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Groundnut (Arachis hypogaea) Piloting, Production, Aggregation, and Marketing in Drylands Agroecologies: A Case Study of Turkana County, Kenya

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Abstract: The study examined the elements of groundnut development in Turkana, specifically the piloting, production, and marketing phases, as well as the system for harvest and aggregation. The study objectives derived from the above elements were (i) analyse data and outcomes from groundnut piloting and production phases, (ii) identify strategic challenges in groundnut production and marketing relevant to drylands agroecologies, (iii) propose a groundnut aggregation model suitable for the Turkana context, and (iv) determine the factors impeding the performance and sustainability of groundnut in Turkana based on the production phase results. 26 groundnut production sites were sampled for investigation from 5 sub-counties of Turkana. The pilot results indicated that at maturity, EUGN 2 (groundnut variety) produced a superior yield of 92 pods per plant in 100 days, in contrast to EUGN 1 and indigenous groundnut varieties, which gave 88 and 48 pods in 105 and 95 days, respectively, establishing EUGN 2 as the optimal variety for Turkana agroecology. The production phase results indicated that among the 26 agricultural sites, the arable land encompasses 22,093 acres, of which only 8,663 acres (39.2%) are cultivated with various crops. Additionally, the land allocated for groundnut cultivation measures 9,810 acres, which, if fully utilised, has the potential to yield 11,772 metric tonnes of unshelled groundnuts valued at KES 1.413 billion. The crop value is able to transform the economy and the wellbeing of the populations in Turkana. The actual production of groundnuts was subpar due to several systemic challenges, including inconsistent yields, absence of a market-orientated business strategy, fragmented and diminutive farm plots, inadequate mechanisation, and a deficient governance structure in farm leadership. Additional challenges included delayed produce off-take by aggregators, delayed payments to farmers, accumulation of aflatoxins especially during the production phase, an ineffective aggregation strategy, and imprecise data for decision-making. The study advocates for thorough feasibility assessments, enhancement of governance frameworks in production areas, land consolidation and mechanised labour, deployment of technical and scientific expertise in managing groundnut value chain elements, continuous access to improved seed systems, and the establishment of viable and competitive product aggregation and market access models as key areas for action.

Keywords: *Groundnut production, Aggregation, Marketing, Drylands, Agroecology, and Market access, Turkana County.*

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Introduction

The agricultural sector is essential to Kenya's economy, accounting for 33-36% of GDP and sustaining the livelihoods of 80% of the people. In Turkana County, 67% of the population depends on agriculture, primarily livestock; nevertheless, climate change challenges have compelled many to reduce herd sizes or transition to seasonal crop cultivation. Groundnuts are emphasised as an essential crop for food security and soil improvement, leading Turkana County to formulate a strategy aimed at enhancing production, managing crop yields, and marketing. Notwithstanding obstacles including significant rainfall fluctuation and insufficient certified seeds, favourable agro-ecological conditions are present for groundnut agriculture, particularly within Turkana's potential irrigation schemes.

The groundnut strategic intent for Turkana County recognises obstacles to efficient production and marketing, such as inadequate infrastructure and restricted access to capital, while also utilising opportunities enhanced through partnerships, market integration, and technological advancements. The Turkana County agriculture policy seeks to mitigate socio-economic shocks hindering the successful cultivation of this crop, emphasising the necessity for resilience against climate change effects, diminishing production resources, and unstable market.

Literature Review

Food safety and security continue to be significant in developing countries, and groundnuts stand to be one of the most globally preferred crops not only for food security but also for income and nutrition security (Anno, Nakeno, & Erukon, 2025). This assertion is in line with Njoki et al. (2024), where groundnut is regarded as one of the most vital crops for human use. However, suboptimal productivity relative to the potential of current crops, attributable to biotic, abiotic, market, and policy influences, results in unfavourable food production trends. According to the studies

by FAO (2022) and Konate (2020), areas employing enhanced groundnut cultivars obtained superior yields relative to those utilising indigenous varieties, and disease infestation is directly correlated with declining yields. The study by Anno and Nakeno (2025) with regard to dryland crop farming outcomes asserts that reduced productivity may arise from social, cultural, and economic inequalities that hinder access to advanced technology, production resources, and potential markets.

Enhancing groundnut yield and quality can be achieved through the development of superior cultivars and the implementation of supportive policies for agronomic inputs (Njoki et al., 2024). Sub-Saharan Africa has developed over 100 enhanced groundnut cultivars in the past two decades to improve output (Abady et al., 2019). Nigeria is the leading groundnut producer in Africa, with a productivity of 3.3 to 4.2 million tonnes, followed by Sudan, Senegal, Tanzania, and Chad, which average 2.04, 1.2, 0.95, and 0.88 million tonnes, respectively, over the past decade (FAO, 2022; Konate, 2020). Kenya produces approximately 21,000 tonnes annually with an expanding market. However, output levels are fluctuating, similar to other African nations because of several contributing variables, including volatility in agricultural techniques, seed policy regulations, and meteorological conditions. Additionally, producers show inconsistent improvements in output relative to the available arable land, which causes productivity to significantly decline or stagnate, thereby jeopardising food security and agricultural exports (Abady et al., 2019).

Regions such as Nigeria, Sudan, Ghana, and Chad, characterised by elevated output, demonstrate a greater harvest area compared to countries with diminished production (Konate, 2020). The trend of a substantial groundnut production area combined with low yields indicates that performance is falling short of its potential. Subpar productivity constrains food security and the export of the commodity to local, regional, and international markets. It is also emphasised in the Akpo et al. (2021) study that the creation of drought- and disease-resistant cultivars, along with the reduction of aflatoxins, serves as a foundation for revitalising groundnut productivity in Africa. Also, the creation of novel cultivars through breeding methods and genomic modification emphasises resistance to leaf spots, rust, drought, groundnut rosette, aflatoxins, and enhanced nutritional quality (Abady et al., 2019; Ndung'u et al., 2013).

An experimental study undertaken in Nigeria to assess the yield results of local or popular varieties (Barberton) and enhanced types (Gubeish), in conjunction with intensification parameters such as plant density and soil enrichment, demonstrated that the enhanced variety (Gubeish) exhibited a 20% greater productivity compared to the native variety, even prior to seed priming, as noted by Abdalla et al. (2018). Consequently, enhanced varieties may be ascribed to superior production resulting from increased resistance to diseases, pests, and unfavourable environmental conditions. The deficiencies in the advancement of variations stem from insufficient study elucidating the genomic traits that might prosper in particular regions. The indiscriminate adoption of enhanced varieties could be mitigated by implementing a series of research initiatives aimed at customising seed types to correspond with the productivity determinants in individual countries. These results are in line with the findings of the study by Daudi et al. (2021) that relate the viability of genes to the crop yield outputs.

Kenya has four primary groundnut cultivation regions with differing productivity: Nyanza (56% of production), Western (22%), Eastern (11%), and Rift Valley (8%) (International Crop Research Institute for the Semi-Arid Tropics, 2020). The predominant cultivated varieties in the region are the runner type and the bunch type, maturing in 90-100 days and 60-75 days, respectively. Nonetheless, the indigenous varieties exhibit worse quality and yield relative to the enhanced cultivars (Sinare et al., 2021; Njoki et al., 2023). Farmers utilising enhanced cultivars get around twice the price for groundnuts due to their superior quality and yield compared to those cultivating traditional types. Sinare et al. (2021) study on cropping system suggested that the cultivation of a local variety known as "Chemblambus local" by farmers in Elgeyo Marakwet is characterised by delayed maturity, diminutive seed size, vulnerability to infection, and poor yields of 700 kg per hectare, in contrast to potential yields of 2,000-3,000 kg per hectare. (International Crops Research Institute for the Semi-Arid Tropics, 2020). The large-seeded enhanced varieties yielded profits of $1.20 per kilogram, in contrast to $0.50 per kilogram for the smaller-seeded native types (Sinare et al., 2021).

The above study results correspond with Njoki et al. (2023), indicating that enhanced cultivars cultivated in Nyanza, Kenya, had superior yield outcomes. The yield was assessed through the evaluation of 100-pod weight, 100-seed weight, biomass, harvest index, and total pod weight. The enhanced variety exhibit greater resilience to diseases and harsh climatic conditions, resulting in increased yield. It is found in Bakoye et al.'s (2019) study on limiting challenges affecting groundnut production in Zinder, Niger, that improving policies and programmes that provide access to superior cultivars could enhance groundnut quality and production, thereby bolstering food security in Kenya, Africa, and beyond. The research conducted by Anno and Erukon (2024) on agricultural production in regions with constrained production factors advocates for investments in infrastructure development, particularly water collection systems, to enhance crop yields during erratic rainy seasons and safeguard farmers against crop failures. To reinforce these findings, Anno, Ingutia and Ejore's (2023) study on the maximisation of crop value chains presents that strategic planning and marketing determine the creation of products with value and communicate them effectively to target markets at a profit.

Methodology

This study employed a case study design for a comprehensive analysis of the stages and components within the context of piloting, production, and marketing of groundnuts in Turkana County. The emergence of a new agricultural value chain in the county necessitated the formulation of an effective strategy based on the framework established under the auspices of the Turkana County Government. All 26 production sites throughout five sub-counties of Turkana were evaluated, encompassing 26 focus group discussions (FGDs) with 12 members from groundnut producer associations per scheme, as well as 14 individual interviews with county government extension officers and market offtake representatives.

The numerical data was sourced from records maintained by the county department of agriculture, irrigation schemes, agricultural producer organisations, and farmer records and testimonials. The data was examined to illustrate relationships and proportions of land, percentage utilisation of production sites,

yields per site per acre, and cumulative numbers to compare production output across the production sites in the sub-counties. Qualitative data was evaluated using coding for classification, categorisation into themes, resulting in logical data and information organisation and presentation.

Results and Discussion

Groundnut piloting in Turkana County

The commencement of groundnut cultivation in Turkana County in 2019/2020 was a joint effort by the Turkana County Government and development partners subscribing to the Kalobeyei Integrated Socio-Economic Development Plan (KISEDP), a strategy designed to integrate refugees and the local community in Turkana through social, economic, and self-sufficiency initiatives. The aims of the pilot project were (i) to evaluate the efficacy of enhanced groundnut varieties developed in Kenya within the agroclimatic context of Turkana, (ii) to identify suitable crop varieties for intercropping with groundnuts, and (iii) to bolster the capabilities of local farmers and agriprenuers in Turkana County to cultivate high-quality groundnuts for both domestic and commercial markets.

Groundnuts function as both a cash crop and a food source, offering great nutritional benefits and venturing into this crop value chain was mean to improve community food security, income, and nutrition, thereby promoting year-round self-sufficiency, especially among refugees and at-risk host community groups. Initial collaborative research conducted by stakeholders in Loima and Turkana West sub-counties together with stakeholder consultations, validated the appropriateness of climatic and agro-ecological conditions, as well as governmental endorsement for groundnut growing in Turkana County. Three sites were selected for the pilot experiments: Nanyee in Loima Sub- County and Natiira and Kalobeyei Integrated Settlement in Turkana West Sub-County.

A three-day training on groundnut production was held to provide government officials, Farmer Field School facilitators and farmers with essential information, skills and attitudes for the proper management of the trial project. The training program offered by Egerton University and the Turkana County Government's Department of Crops concentrated on various aspects of groundnut production, encompassing agronomic techniques, field trial methodologies and protocols, quality management of research treatments, data collection and reporting, post-harvest handling, and marketing strategies. The assessed groundnut varieties comprised Egerton University Groundnut 1 (EUGN-1), a large brownish type; Egerton University Groundnut 2 (EUGN-2), a medium-sized red variant; and a local groundnut variety from Kerio Valley, a little red variety that is highly liked in Kenya. Each variety comprised eleven treatments, each replicated three times across all trial plots. Project partners, primarily FAO, INSTA Foods, and the International Finance Corporation (IFC World Bank Groups), conducted multiple joint monitoring missions to improve field crop management.

Harvesting missions were executed with all stakeholders present. During harvesting, the days to maturity for EUGN 1, EUGN 2, and local groundnut varieties were recorded as 105, 100, and 95 days, respectively, with average pod counts of 88, 92, and 48 pods per plant. The EUGN 2 variety displayed the highest yields, whereas the EUGN 1 variety showed almost similar yields but with a postponed maturation period. The local variety flowers and develops early, producing fewer pods but can be successfully cultivated under rain-fed circumstances, whereas the superior varieties may necessitate supplementary irrigation to effectively complete their cropping cycles. The indigenous cultivar is likely to endure the effects of dry seasons if planted timely and adequately tended. The superior varieties are suitable for commercial production, especially in irrigation schemes in Turkana County and prospective rain-fed agricultural zones, whereas the local groundnut variety can be grown on individual farms and in backyards for household consumption and to alleviate nutritional crises, particularly in malnourished households.

The testing results for the EUGN-2 variety, preferred by INSTA Foods, were promising in terms of field performance, environmental adaptability, and yields that met the threshold for economically feasible production. Given that groundnut is an innovative crop type in the region, extensive training for farmers and government extension agents is crucial to facilitate learning, adoption, and replication of groundnut cultivation technologies. This program will equip stakeholders for field-level production, the development of crop value chains, marketing, management of investor relations, supervision of product consumption outlets, and improvement of home nutrition and recipes utilising groundnut commodities. The groundnut production strategy for Turkana County must include seed bulking to improve seed proliferation, accessibility, and cost for farmers. Below is the photo of a groundnut pilot site in Turkana County.

Figure 1: Groundnut piloting in Natiira, Turkana West Sub County

Identified opportunities for groundnut production in Turkana

The pilot phase yielded several insights that, if effectively used, might enhance the success of groundnut production and value chains. The current opportunities in Turkana comprise:

- Appropriate agro-ecological conditions, including optimal temperatures, promote rapid growth and drying of groundnuts, hence inhibiting fungal proliferation and aflatoxin development;
- Prospective public-private partnerships are opportune for establishing alternative marketplaces via contractual agreements. Public-Private Partnerships furthermore offer a means to develop and enhance marketing infrastructure.
- Regional integration initiatives like NOREB and FCDC create opportunities for Inter-County Trade by facilitating new and expanded markets.
- Existence of numerous development partners prepared to assist farmers and traders with agribusiness expertise;
- The expansion of ICT and innovative technologies in Kenya presents a potential for enhanced and efficient marketing and trade of groundnuts; and
- The food security and nutritional issues in Turkana can be mitigated by households including groundnuts into their regular diets. This can enhance nutrition for people of all ages, not just those under five.

Figure 2: Farmer Field School (FFS) harvesting the groundnut crop in Natiira, Turkana West Sub County

Groundnut Production Phase

The study established that the determinants of groundnut output in Turkana County are substantial. Turkana County possesses over thirty operational irrigation schemes, additional area suitable for rainfed agriculture, and optimal soil types for groundnut cultivation, including sandy, sandy loam, and clay loam soils. The soils are fertile, unexploited, and uncontaminated. The strong commitment and enthusiasm of host and refugee community farmers, Farmer Field School groups, women's and youth groups, community leaders, supportive partner agencies and well-distributed County Department of Agriculture offices are determined to exploit groundnut production and the development of product value chains.

The following table presents the mapped potential areas for groundnut production in Turkana County. It also shows the proportion of land (normally put) under crop cover and the overall land utilisation in the area.

Table 1: Mapped areas for groundnut production in Turkana County

S/no	Sub County	Irrigation Scheme/Spate Irrigation	Size of arable land suitable for groundnut production	Current land under crop production	% Scheme utilization
1	Turkana South	Nakwamoru	600	20	3
		Kapelbok	450	50	11
		Simaelele	400	100	25
		Juluk	200	80	40
		Katilu	3000	600	20
		Lokapel	400	300	75
		Nawopeto	600	280	47
2	Turkana East	Morulem	2000	1050	53
		Elelea	1500	800	53
		Lokubae	2200	1200	55
3	Turkana Central	Nadoto	723	433	60
		Naoros	300	120	40
		Ngimuriae	800	400	50
4	Loima	Kangalita	1200	720	60
		Nanyee	800	300	38
		Naipeker	700	200	29
		Kalemunyang	300	150	50
		Naipa	400	100	25
		Kolioro	2200	450	20
		Kotela	560	200	36
		Moruese	480	160	33
		TISA	400	150	38
5	Turkana West	Nasinyono	300	150	50
		Lokipoto	700	300	43
		Lokichoggio	580	200	34
		Aagis	300	150	50
	Totals		**22,093**	**8,663**	**53**

The above analysis shows that Loima subcounty has the largest arable land, with 36% of it under crop cover. The second and third largest are Turkana East and Turkana South, with 5,700 and 5,650 acres of arable land, where 53% and 32% are put under crop, respectively. The fourth and fifth areas are Turkana West and Turkana Central sub-counties, with 1,880 and 1,823 acres of arable land, respectively, of which 42% and 50% are under crop. Putting more land under crop in areas with limited irrigation demonstrates the high willingness of farmers in those areas to produce their own food. This finding also corresponds with high food insecurity in areas that depend largely on rainfed agriculture. This motivation demonstrates farmer resilience and drive for economic self-reliance.

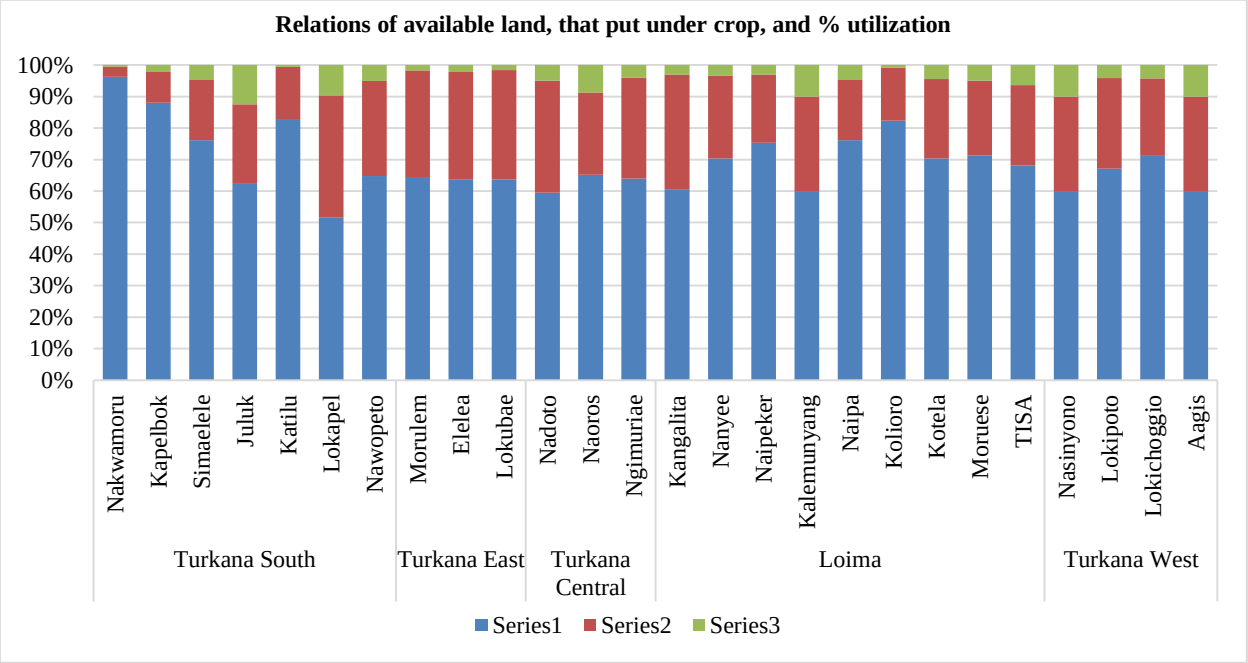

Figure 3: Available land and utilization

The table below shows the consolidated land in the selected irrigation and rainfed farms that can be put under groundnut production and the minimum yield per acre (unshelled groundnut).

Table 2: Consolidated land for groundnut production in Turkana County

Sub County	Irrigation Scheme/Spate areas	Size of arable land suitable for groundnut production	Land for groundnut production (acres)	% Land for Groundnut production	Yield per planting season @ 1.2 MT/Acre
Turkana South	Nakwamoru	600	186	31	223
	Kapelbok	450	150	33	180
	Simaelele	400	210	53	252
	Juluk	200	189	95	227
	Katilu	3000	1080	36	1296
	Lokapel	400	420	105	504
	Nawopeto	600	294	49	353
Turkana East	Morulem	2000	1108	55	1330
	Elelea	1500	790	53	948
	Lokubae	2200	1020	46	1224
Turkana Central	Nadoto	723	355	49	426
	Naoros	300	146	49	175
	Ngimuriae	800	360	45	432
Loima	Kangalita	1200	576	48	691
	Nanyee	800	330	41	396
	Naipekar	700	270	39	324
	Kalemunyang	300	255	85	306
	Naipa	400	153	38	184
	Kolioro	2200	795	36	954
	Kotela	560	228	41	274
	Moruese	480	230	48	276
	TISA	400	225	56	270
Turkana West	Nasinyono	300	175	58	210
	Lokipoto	700	210	30	252

Lokichoggio	580	30	5	36
Aagis	300	25	8	30
Totals	**22,093**	**9,810**	**Ave. 47**	**11,772**

The above analysis presents groundnut production potential in Turkana County. If all the selected production sites are put into maximum use, including proper deployment of factors of production, it is estimated that the yield output per season shall be 11,772 MT. With the farm gate price of unshelled groundnuts being KES 120, the gross value of the harvest will be 1.413 billion Kenyan shillings per season.

The figure below shows relationships in the sizes of irrigation schemes and the land allocated for groundnut production. The analysis shows that Loima sub-county is the highest potential area, where 432 acres of land are allocated for groundnut production with an average of 48 acres per irrigation scheme. Loima also has numerous sites identified for groundnut production along the River Turkwell. Turkana South is the second highest potential area. Although few sites are identified for groundnut production, the average land per site is 57 acres. The third and fourth highest are Turkana East and Turkana Central, with land allocation being 154 and 143 acres and average land per site being 51 and 48 acres, respectively. The least area for groundnut production is Turkana West, with 102 acres allocated for groundnut production with an average of 25 acres per site. Turkana West does not have established irrigation schemes. Production is purely rainfed.

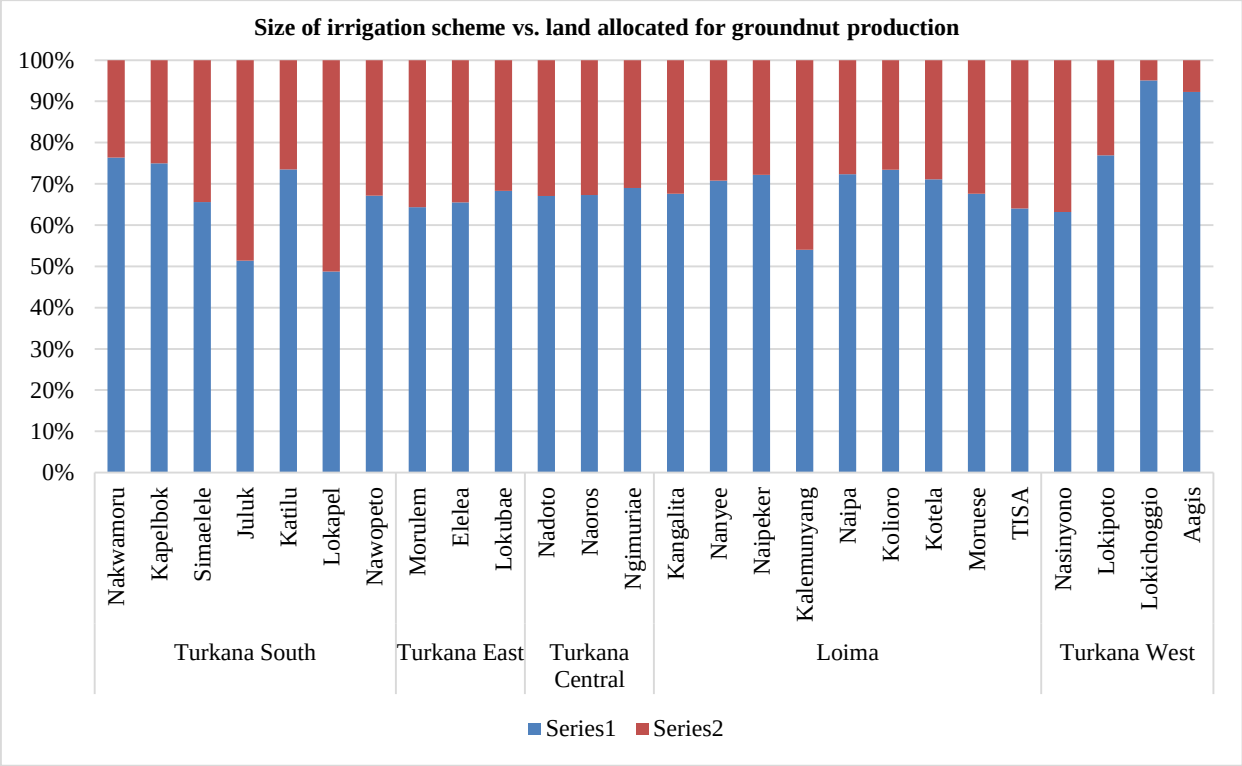

Figure 4: Proportion of land allocated for groundnut production

Strategic challenges in groundnut production and marketing in arid regions

Groundnut production in Turkana County involves not only farmers in production and marketing but also agricultural and food security partners through training and consultative forums to analyse strategic issues relevant to establishing groundnut as a cash and food crop, thereby impacting community food, income, and nutrition security. The subsequent strategic domains designated for management are as follows:

Insufficient availability of premium groundnut seeds

It is apparent that certified groundnut seeds are not easily accessible to numerous farmers in the country due to the limited number of stakeholders engaged in their manufacturing and distribution. This inadequacy is severely impeding groundnut output in Turkana. To guarantee a sustainable supply of quality seeds, the strategic interventions identified encompass the establishment of an effective season-long community seed system, the allocation of additional land for seed production within the identified potential irrigation schemes and farmlands in Turkana, and the formation of linkages with other private seed producers, including Kenya Seed, KALRO, Seedco, and Western Seed, through public-private sector partnerships.

Insufficient knowledge and expertise in groundnut cultivation

The study emphasises the necessity of providing farmers and other value chain participants with essential skills in groundnut production. This is effectively achieved through the establishment of farmer field schools for practical knowledge dissemination, the promotion of community-based extension and lead farmer extension service delivery models in all potential groundnut production areas, and the training of frontline extension officers in agronomic practices for groundnut production. To enhance the capacity of extension officers for improved service delivery, it is essential to recruit additional extension officers to support the

groundnut value chain, establish Agriculture Training Centres (ATCs), and introduce short courses on groundnut production. Furthermore, forming strategic partnerships with training institutions such as Egerton University, Turkana University College, and KALRO for on-the-job training in new technologies and innovations, as well as strengthening Public-Private Partnerships, particularly with private sector extension to supplement public advisory services, are critical strategic initiatives for developing a sustainable and impactful knowledge development and implementation framework for the county.

Restricted access to credit and financial resources

To improve access to affordable credit and finance for groundnut farmers, the establishment of a credit guarantee by the government and partners, assistance for farmers in obtaining and adopting crop insurance to facilitate credit access from financial institutions, and support for innovative contract farming systems will generate additional opportunities for farmers to finance their production and marketing endeavours. Furthermore, facilitating the establishment of cooperatives, village savings, and credit organisations that provide alternative credit sources; fostering the development and implementation of innovative mobile technologies for agricultural financing; and creating structured trading systems such as Warehouse Receipt Systems (WRS) will enhance resource mobilisation among farmers and improve the management of groundnut production.

Infestations, pathogens, and non-native flora

Turkana County's agroecology harbours several pests and diseases. During dry seasons, farms provide as optimal habitats for various insect and bird species, many of which feed on crops. To improve the safe application of pesticides and sustainable pest and disease management in groundnut farms, the prioritised strategic interventions encompass the promotion of innovative technologies for surveillance, control, and management of pests and diseases; the application of acceptable quantities and qualities of agrochemicals; and the establishment and promotion of Integrated Pest Management (IPM) practices. The establishment of strategic partnerships with research organisations for the development of biological pesticides, as well as the formation of alliances for the control and management of Prosopis juliflora, are strategies to mitigate the effects of pests, diseases, and invasive species on groundnut production in the county.

Ineffective irrigation system schemes

To enhance the efficiency and management of irrigation systems in Turkana for the purpose of augmenting the production of groundnuts and other value crops, the study identifies the rehabilitation and expansion of irrigation schemes, the provision of small-scale canal de-silting machines, the development of climate-resilient irrigation system designs, the proper operation and maintenance of schemes, and the promotion of effective governance as essential for achieving improved performance. To tackle the deficiency of inclusivity in agricultural value chains and promote gender equity in the groundnut value chain, it is emphasised that facilitating access for women and youth to productive resources such as land, credit, and extension services will incentivise their engagement and enhance their involvement in the various aspects of the groundnut value chain.

Inadequate aggregation and storage facilities

The predominant Turkana farmers are smallholders, generating inadequate outputs for economic sustainability. The consolidation of farmers can establish larger and more reliable supply chains to meet market demand. In Turkana County, prospective groundnut aggregation hubs comprise Kangalita, Tiya, Morulem, Lokubae, Moruese, Nadapal, and Tiya, necessitating connections to production sites and infrastructure for monitoring moisture and aflatoxin levels, in addition to adequate storage facilities. Substandard rural road networks and insufficient transportation infrastructure elevate transaction costs for farmers and limit market access. Local markets frequently lack critical infrastructure, like electricity and storage, leading to substantial output losses, particularly impacting the groundnut value chain.

Unutilised potential for market access and processing capabilities

A primary strain in agricultural marketing is guaranteeing that farmers obtain equitable pricing for their products. Value addition provides opportunities for farmers and other stakeholders to attain increased returns per product sold. In Kenya, a significant portion of agricultural products, such as groundnuts, is marketed in raw or semi-processed forms, thereby forgoing potential revenue and employment opportunities. At now, groundnut growers and traders in Turkana County are restricted to fundamental processing activities, including sorting and packaging. Enhanced investments are required to promote more lucrative value addition activities throughout the supply chain.

Farmers' cooperatives and contract farming in Turkana County possess the capacity to establish organised marketplaces for groundnuts and other agricultural products. Cooperatives enable farmers to capitalise on market opportunities, alleviate market disruptions, and safeguard against middleman exploitation. Currently, there are no cooperatives specifically for groundnuts in the region; the existing cooperatives are centred on other agricultural commodities. The governance of these cooperatives is deficient, constraining market engagement, negotiating leverage, and economies of scale. Moreover, contract farming is still foreign to some farmers, underscoring the necessity for improved capacity-building initiatives.

Ineffective market information systems and agriculture capabilities

Marketing information systems are essential for optimising marketing efficiency and augmenting pricing information. They facilitate the transmission of price signals between consumers and producers, enabling farmers to secure more advantageous agreements. In Kenya, numerous farmers and local traders are deprived of access to market information, resulting in their reliance on urban dealers, who possess current market data, for the sale of their produce. A variety of agribusiness opportunities within the groundnut value chain include production, processing, value addition, and services such as transportation and warehousing. Access to finance, equipment, and infrastructure is essential for improving smallholder productivity. Many smallholder farmers lack collateral, resulting in uncertainty for financial institutions who are reluctant to lend due to variable production and significant price fluctuation.

Inadequate regulatory and commercial environment

Marketing agricultural products in Kenya is affected by several taxes, including levies, VAT, and tariffs, which can reduce revenues throughout the agricultural value chains. The fiscal policies will also affect groundnut production and marketing in Turkana County, thereby deterring investment in the groundnut value chain. Moreover, food safety rules will impact pre- and post-harvest procedures as well as value addition for farmers and dealers.

Groundnut aggregation model for Turkana County

Aggregation framework

The study also assessed the aggregation in the groundnut product value chain which means producers coming together to: strengthen their likelihood of achieving production and market goals for sustainability; enable farmers to achieve economies of scale along the agricultural value chain; meet the standards required by the market; and address their barriers to accessing the market and agricultural inputs. The study identified aggregation as part of groundnut marketing and market capitalization. The critical components of the groundnut value chain to be capitalized upon include production that meets the market needs and standards, collection of products to designated points, transportation, sorting and grading, housing and storage, processing, information sharing, transaction systems, and stakeholder relations. The study confirms that these value chain components will be realized through sufficient market network, required financial ability, proper knowledge relevant to the value chain, and by making aggregation become a win-win business situation for all actors involved.

The process of aggregate production planning

In Turkana County context, to realize and maintain groundnut aggregation, determination of the input and output factor relationship will facilitate production, marketing and increased consumption of groundnut products, as outlined in the table below.

Table 3: Groundnut production input and output factors

Input	Output
Strategic objectives (production, market, and partnerships)	The number of aggregates/workforce/labours
Demand forecast (mapping market needs/capacity)	Inventory levels, raw materials
Government and aggregator policies	Regular/overtime production in units/costs involved
Financial status	Backlogs, backorders, lost sales (high or low demand)
Status of capacity	subcontracted production, long-term production partnerships
Business environment (understanding preconditions: social, economic, political, environmental, legal, technological)	Competition management/rivalry/farmer exploitation and behavioural rationalization and management

Aggregation centers

These are the designated trading places for locally grown groundnuts (produce). Farmers nominated as market aggregators organize produce to be transported to jurisdictional aggregation centers, as per the defined chain of product aggregation. Buyers who know products in demand and prices come to the aggregation centers to purchase produce in bulk from the aggregates. The terminal groundnut aggregation centers will be a one-stop service center where farmers get different forms of agricultural support, e.g., quality seed, farm management information, and digital financing systems.

A small percentage (mark-up) of the price paid is kept by the aggregation centre to cover costs for investment and operations. The aggregation centers will have farmers more connected, organized and more empowered. The organized trading and sales based on agreements with aggregators will increase income opportunities for local farmers, which are critical to the farmer households' food security and nutrition.

Meeting aggregator demand

To manage the aggregator demand, the groundnut aggregates (farmers), based on the prevailing business scenarios, will adjust their capacities to meet production output targets, make minor variations in demand, manage the demand trends of the aggregators and the market, and ensure proactive demand management (PDM) as a means of reducing inventory-related costs and improving the overall profits from the aggregation of produce.

Market models for aggregation

In the context of Turkana, the groundnut aggregation will employ the following market systems:

- **Spot market deals:** The individual farmers will be accessing farm gate sales, local (periodic) markets, and auctions at aggregation centers. The farmer groups will have their produce grouped in villages, and the produce transported to local buying centers with some processing equipment (shellers). This process will ease farmer groups selling their groundnuts directly to traders or main buyers. Group transporters can take this approach as a business opportunity.
- **Contracts:** Individual tenant growers will aggregate groundnuts at farm/scheme level and sell them to the main buyer. The same farmers, based on their capacities, can collect the produce from the farm for delivery to the buying centers or processing plants. After sales, the tenant growers can then pay the landowners the land rents. Independent groundnut growers collect the produce and sell it to the main buyer at aggregation

centers. Like individual farmers, group farmers can also collect the produce and deliver it to the buying centers or processing plants.

- **Collective sales:** Tenant groundnut growers are grouped for logistical convenience and for negotiation with scheme managers, but usually they lack the independence of other producer organizations. Independent groundnut growers are put in groups to maintain the buyer (aggregator).

Aggregation model for irrigation schemes

The proposed aggregation model identifies the following components as critical to the functionality of the aggregation of groundnuts in Turkana County:

Locations of aggregation centers:

The aggregation of groundnuts will be done at different levels.

- **Level One:** It begins with selected farmers who are commercial groundnut growers and aggregates. They will ensure good quality groundnuts are produced. At farm level/own stores, they will do the drying, sorting, and packaging (unshelled) in designated sacks.
- **Level Two:** Depending on nearness to the main scheme store, the aggregates can take their produce to the main scheme store hereby referred to as an aggregation centre. If the production sites are sparsely distributed, the farmers will form clusters and find a store where they will start aggregating the produce before finally transporting it to the main aggregation center.
- **Level Three:** Due to accessibility factors important to aggregators accessing mini and main aggregation centers, farmers in the form of a cooperative may establish an aggregation center in the main highway towns of Kakuma, Lodwar, Lokichar, Kalemngorok, or Kainuk for purposes of offtake convenience.

The management of aggregation centers

The **Level One** mini aggregation centers will be managed by a farmer's committee at groundnut production sites (farm level). The **Level Two** center will be managed by a farmer's cooperative, and **Level Three** will either be managed by a farmer's cooperative or by the aggregator, depending on who can afford the cost of establishing and running an aggregation centre situated in a town area.

How produce will get to the collection centers

It is the responsibility of individual farmers, farmer groups, and cooperatives to ensure the aggregate (groundnuts) reach the stores of the chosen aggregation level using different modes of transportation. Each level of groundnut aggregation poses good business opportunities for stakeholders. The aggregator, in collaboration with aggregate cooperatives, will invest in a Level 3 aggregation system. A good and sustainable supply of produce to aggregation centers guarantees consistency of aggregation, sales, transactions, and safety of the produce.

Groundnut aggregation model framework

The following is proposed aggregation model for groundnuts in Turkana based on evidence.

Table 4: Groundnut aggregation model

Aggregation levels	Aggregation chain	Requirements
Level 1 **(Farm level)**	**Farm level groundnut aggregates** Independent farmers (stores); Tenant growers (stores); Farmer groups (stores)	- Organized farmers - Production standards (Yield quality, quality, hygiene) - Farm/Scheme management system
Level 2 **(Scheme level)**	**Scheme level groundnut aggregation** Scheme 1 Aggregation center; Scheme 2 Aggregation center	- Organized farmers cooperatives - Post-harvest handling standards - Scheme/store management system
Level 3 **(Urban level)**	**Urban center groundnut aggregation** Urban Aggregation C. 1 (North); Urban Aggregation C. 1 (South)	- Organized agribusiness cooperative - Workable aggregator supply chain system - Effective communication - Timely transactions
Foundation: Accessible and dependable factors of production (land, water, knowledge, finance, labour, production inputs, GAP); Agriculture policy; and farmer and private sector commitment.		

Challenges affecting groundnut production in Turkana

The first groundnut production project that was studied took place between the years 2020-2024, and it is said to have encountered a number of challenges, which include:

- Low and inconsistent production even during reliable rainy seasons and abundance of river waters for irrigation; low production volumes recorded every harvest; labour provided by farmers was weak because it was manual; fragmented land could not allow for a harmonised approach to planting and routine management practices; poor economics of production; and low benefits from costs incurred.
- The enterprise's business model lacked robustness in market capitalisation. The assumption that households might consume certain volumes of groundnuts directly from the farm undermined the market system approach, which mandated that all production be monetised prior to consumption. The trade-off established a loophole that may result in significant harvest losses due to unrecognised markets, resulting to an inability to meet the minimum volumes specified in the contracts signed

with offtakers. This renders the business model employed for groundnut production flawed, erratic, and untrustworthy.

- The business model failed to rationalise farmers' behaviours in adopting optimal methods for crop management both in the field and post-harvest, despite the novelty of the crop to them. The extension services, training, and exposure provided were insufficient to facilitate rational decision-making among farmers.
- The enterprise also suffered from weak governance structures, such as irrigation committees that do not perform their tasks effectively; an insufficient number of extension workers to farmer ratio; and inconsistencies in the technical services and monitoring services that are offered by the actors.
- The offtake of produce by the aggregator was always being delayed, which resulted in post-harvest losses and high costs of storage. Many farmers were demoralised as a result of delays in paying them for the products that they delivered to the aggregator. These factors, in conjunction with the low returns from the crop as a result of diseconomies of scale, led to some farmers going for the cultivation of other crop value chains rather than groundnuts.
- Laboratory tests conducted during the pilot phase revealed that the crop contained no aflatoxin. During the production phase, this challenge began to manifest itself, and a significant portion of the responsibility was placed on the manner in which the produce was handled and stored. Because of this circumstance, the intended market exhibited reluctance, which resulted in farmers selling their harvest to other offtakers and households.
- Although the county administration had initiated a groundnut production strategy, it was not successful in attracting finances (even within government itself) that would have allowed for the continued exploration of groundnuts as a cash crop and food crop. When the donor-funded groundnut production project came to an end in 2024, practically all of the developments that had been undertaken came to a stop as well. This meant that an excessive reliance on donor funds to maintain groundnut production was not going to be successful.
- No effective aggregation model was implemented to facilitate the mobilisation of produce from farms to scheme levels and aggregation centers along the primary highways. Neither the farmers nor the aggregators (offtakers) committed to establishing an effective aggregation system. This resulted in significant inconsistencies in post-harvest management, leading to numerous issues, including aflatoxin accumulation, harvest loss, and a lack of responsibility.
- Numerous data deficiencies were reported, including erroneous figures regarding the number of farmers engaged in groundnut production, inaccurate area cultivated, flawed yield recordings, inadequate accountability, and insufficient management of the produce to satisfy the minimal supply demands of primary offtakers. Absence of data distorted reporting and engendered significant mistrust among stakeholders and community-based facilitators.
- The establishment of a community seed system did not come to fruition, resulting in difficulties accessing improved seed varieties. This problem hindered timely planting and resulted in an excessive dependence on Egerton University, which was unable to provide the necessary seeds promptly and in sufficient quantities.

Conclusion

The study concludes that, despite challenges related to production factors, the potential determinants for groundnut production in Turkana County and similar contexts can be substantial and capable of meeting the needs of both local and external markets. This outcome depends on the prudent and evidence-based deployment of resources and cognisance of the risks that can derail progress. To ensure the success of groundnut production ventures, a comprehensive feasibility evaluation led by knowledgeable stakeholders is essential. Technical organisations to manage the piloting phase, which depicts the production and upscale phases, and proper planning is key to achieving successful outcomes.

With farmer morale in mind, land consolidation can enhance economies of scale and foster the accumulation of farmers' efforts, resources, and time management. A robust, market-orientated business model is essential, concentrating on agricultural output, processing, and diverse consumption. Replacing the irrigation and farm management committees after a 3-4-year tenure may improve governance. Furthermore, strict adherence to farming contracts is critical to avoid delays in supplies. It is therefore recommended that Turkana County should invest in agriculture enterprises using empirical evidence to inform production, aggregation, and market access systems, and effective data management and decision-making tools are vital for stakeholder education and enterprise system protection.

Recommendations for Application

To achieve efficient, effective, and significant groundnut production in Turkana County and comparable agroecologies, the following should be incorporated into the strategy:

- A comprehensive feasibility and baseline evaluation must be conducted by well-informed stakeholders possessing technical expertise and community experience, emphasising the importance of production elements at the core. The findings of this research should inform the development of a groundnut production project with explicit standards for each component of the crop value chain.
- Piloting is a crucial phase that must be overseen by technical and practical organisations. The pilot results must be analysed carefully to facilitate the selection of optimal varieties for production. This phase must be managed with substantial trust and consistency to prevent the presentation of erroneous outcomes that promote the interests of specific parties.
- The production stage must be meticulously planned and executed to achieve the desired quantities, mitigate risks, and provide satisfactory outcomes for all parties

involved. At this stage, it is essential to retain farmer morale to preserve the momentum for investment and crop exploration.

- Encourage land consolidation to combine labour and capital and ensure uniformity in the adoption of agronomic and crop husbandry methods, rather than permitting farmers to cultivate crops on their tiny plots. Invest in mechanisation for expedited land preparation and timeliness of planting activities. This will result in economies of scale, conserve time, and foster cooperation among farmers for enhanced advantages.
- Develop a strong, competitive, profitable, and sustainable business model for the enterprise. The business case must be market-orientated and able to enhance agricultural output at the farm level, as well as processing and marketing. It should also concentrate on the consumption of the produce across various prospective markets. Concentrating only on a single market channel is precarious, particularly when influenced by socio-economic and political forces. The business model must elucidate the actions of farmers, offtakers, and consumers to reinforce their motivations for participating in the enterprise.
- There is a significant necessity to invest in the governance systems of irrigation facilities. The scheme committees, the bulk of whom are illiterate, have retained their positions for numerous years. Revamping the system and establishing governance and management for new cohorts will enhance the performance of the schemes, align with existing initiatives, particularly in hunger and poverty alleviation, and generate business prospects in agriculture.
- Strict compliance with the contractual agreements established between the parties engaged in the groundnut industry is vital. The potential for delays in fulfilling the requirements of the agreement, which encompasses achieving optimal supply volumes, prompt offtake and payments, and ensuring crop produce is free from pollutants like aflatoxin, must be meticulously assessed in advance and mitigated at all costs.
- The Turkana County administration should not rely on donor funding to capitalise on agricultural interventions. Crop production is a sustainable endeavour best supported by county financial allocations that adequately address all phases of crop development, including research and piloting, production, marketing, and processing.
- The aggregation model for the crop must be established based on empirical evidence. The model must facilitate the effective mobilisation of the crop and ensure protection at all stages leading to the terminal market. Necessary investments, particularly in establishing effective aggregation locations, merit consideration as a method of preserving the harvest's original form and value.
- Effective data management is essential. This is accomplished via suitable data acquisition and management instruments. The promptness and uniformity in the data mobilisation, processing, and application of outputs for decision-making would safeguard the entire enterprise system while educating all business stakeholders, including farmers.

Recommendations for Future Research

The research delineated the subsequent essential domains for prospective investigation:

i. The feasibility and sustainability of groundnut production in Turkana depend on factors of production, including land, water, labour, and management competencies.

ii. The market for groundnuts, including potential product value chains that may be developed from it.

Disclaimer

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Interest Conflicts

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